Aerospace Technology Working Group

Theme: Future Space Age Technologies

JPL

IVHM Sensors Program

Ed Baroth, Ph.D.
Manager, Advanced Sensor Systems
Jet Propulsion Laboratory,
California Institute of Technology

(818) 354-8339
ebaroth@jpl.nasa.gov

October 26 - 28, 1999 **Phoenix, AZ**

ecb 1

Agenda

- IVHM (Code R) Team
  - Objectives & Recent Activity
- Vehicle Health and Sensors
  - Current Work
- Sensor activities
  - ARC, DFRC, GRC, JPL, KSC, LaRC, MSFC
- Summary

ecb 2

Code R Team Objectives

- Coordinate IVHM activities across NASA Centers
- Support, advise and direct specific program IVHM needs
- Bridge technology gaps and manage development program
  - Coordinate between program needs and identify common technologies
  - Identify technology gaps and lobby for bridge funding
- Interface and coordinate with external interfaces
  - Work with supporting technology programs and leverage applicable resources (i.e., ISE, Instrumentation, etc.)
  - Coordinate with industry, academia and other government agency technology development plans

Recent Activity

- Support 2nd/3rd Generation funding exercise: STAS III - Phase II
- Support specific experiments on X-vehicles
  - X-33, X-34, X-37
- Support Shuttle Upgrade Program

Overview

IVHM Objectives

Increase Safety of:
- Public
- Astronauts and Pilots
- NASA Workforce
- High-Value Equipment and Property

Increase Mission Reliability for:
- Making launch window
- Completing mission

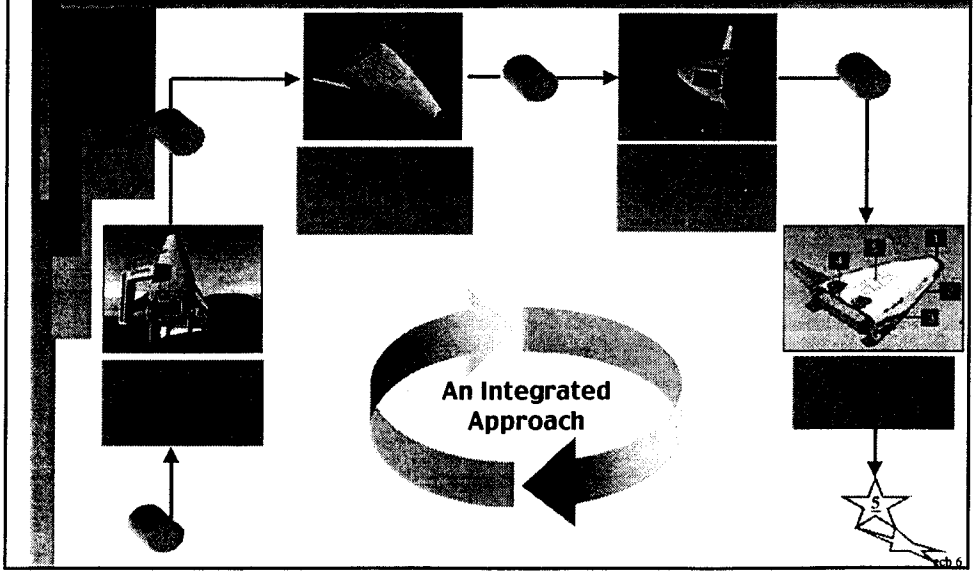
Reduce Operational Cost in:
- Turn-Around time
- Labor
- Maintenance
- Pre-Flight check-out

To accomplish these objectives requires an IVHM system approach at the start of the program with:

- A top-level approach for subsystem testing to understand the physical changes using the IVHM sensors
- A bottom-up approach to use IVHM sensors to understand and improve critical components during the development cycle

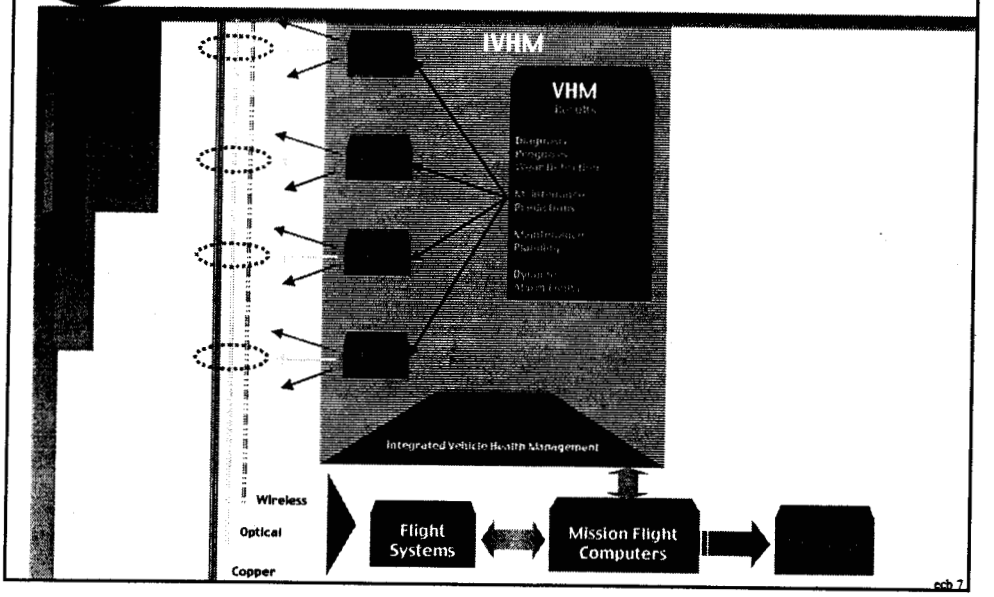
ech 5

An Alpha to Omega Methodology for IVHM

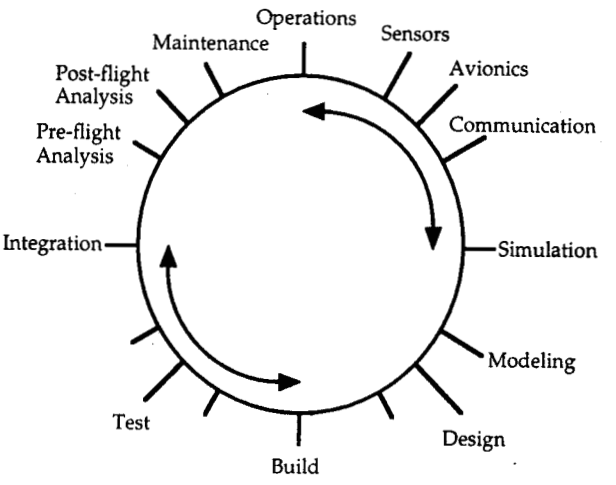


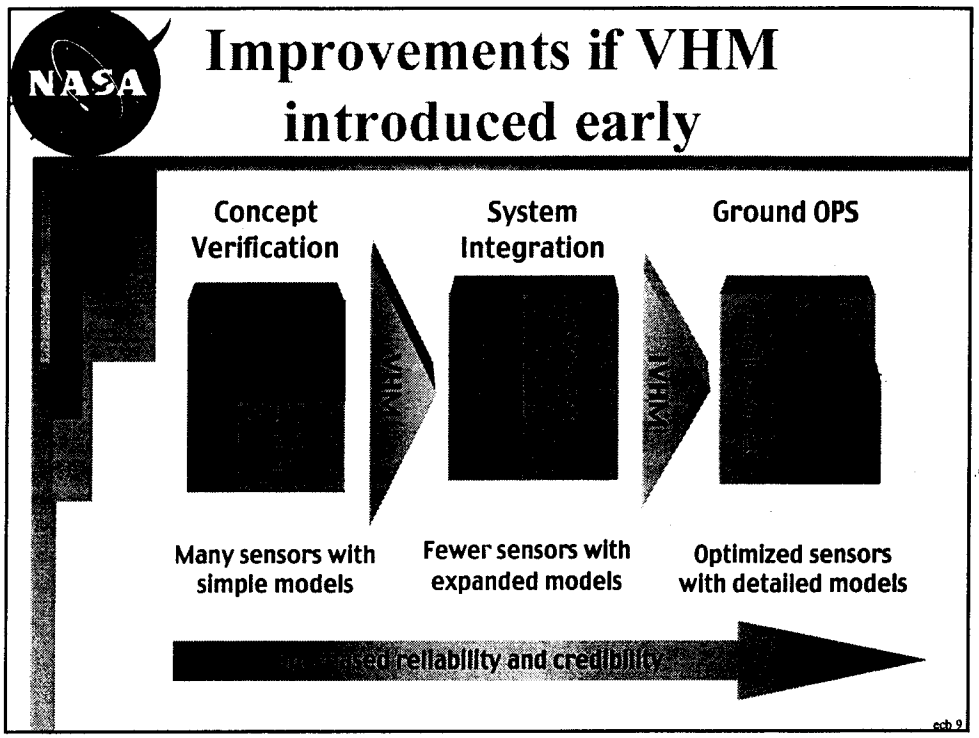
ech 6

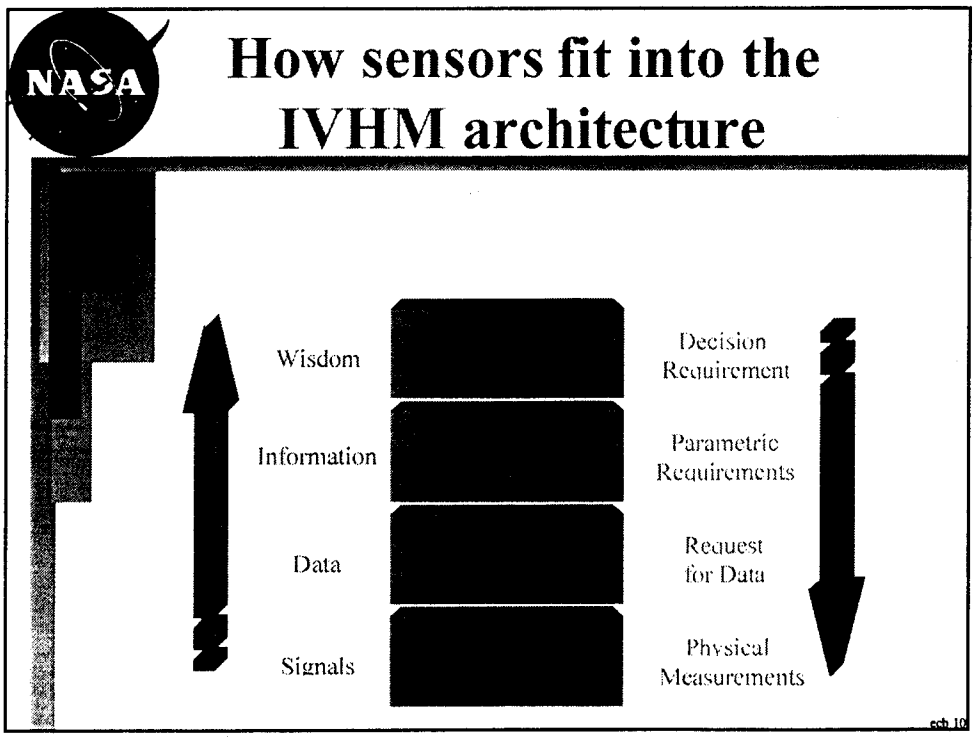
IVHM Architecture



Relation of IVHM to Life-Cycle Costs




Improvements if VHM introduced early
Concept Verification
System Integration
Ground OPS
VHM
VHM
Many sensors with simple models
Fewer sensors with expanded models
Optimized sensors with detailed models
ed reliability and credibility
ech 9


How sensors fit into the IVHM architecture
Wisdom
Information
Data
Signals
Decision Requirement
Parametric Requirements
Request for Data
Physical Measurements
ech 10

Current Analysis

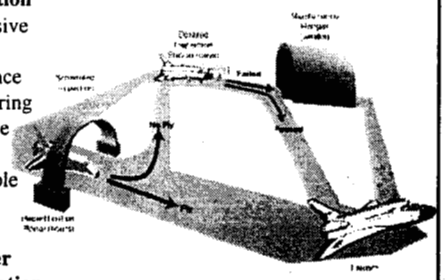
- X-33
  - H_2 Tanks
- Shuttle
  - SSME

IVHM Sensor Contacts

- HQ - Dave Stone <dstone@hq.nasa.gov>
- ARC - Mike Skidmore <mskidmore@mail.arc.nasa.gov>
  - Joan Pallix <jpallix@mail.arc.nasa.gov>
  - Charles Simonds <csimonds@mail.arc.nasa.gov>
- DFRC - Keith Schweikhard <Keith.Schweikhard@dfrc.nasa.gov>
- GRC - Jih-Fen Lei <Jih-Fen.Lei@lerc.nasa.gov>
- JPL - Ed Baroth <ebaroth@jpl.nasa.gov>
- KSC - Scott Wilson <Scott.Wilson-1@kmail.ksc.nasa.gov>
- LaRC- Bill Prosser <w.h.prosser@larc.nasa.gov>
- MSFC- Anthony Kelley <anthony.kelley@msfc.nasa.gov>

ARC

•Rapid Remote Wireless TPS Recertification
- Commercial RFID Tags coupled with passive thermal/mechanical overlimit sensors
- Embedded with no batteries, no maintenance
- Small and lightweight, global TPS monitoring without impact to TPS properties or vehicle weight.
- Designing and seeking designs for resettable passive overlimit sensors.



•In-Flight Wireless Continuous Parameter Monitoring for X-Vehicle Design Verification
- Seeking designs for simple sensor systems to measure TPS parameters throughout the vehicle flight profile (temperature, pressure, stress, strain, impact, chemical change).
- Selected sensor suite will be tested for performance range, reliability and robustness.
- Evaluate feasibility for long term miniaturization of selected sensors and ability to combine with wireless communications.

•Flight Tests Planned for Selected Sensor Systems
- X-34 tests of gap heating thermal overlimit sensors in FY01.
- Shuttle tests of gap heating thermal overlimit sensor in FY01- resettable in FY02.
- X-34 and Shuttle flight testing of other selected sensors in FY02 to FY06.

ARC

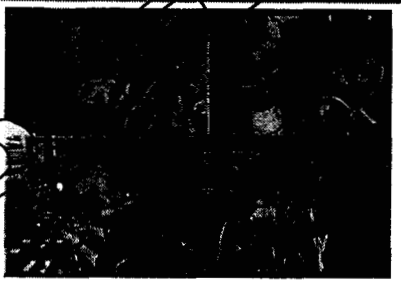
Science Payloads IVHM would develop sensors, sensor systems, habitats, and associated communication structures to seamlessly integrate payload systems with overall IVHM concepts and designs.

Improved safety of crew and vehicle
- Science Payloads IVHM uses technologies, comm. structures, & data mgmt. common to other IVHM systems
- Reduced dependance on crew intervention for payload ops - increased science flexibility and science return
- Continually updated status of Science Payload with PI interaction possible
- Directly supports paperless, wireless on-orbit environment, automated mission timeline scheduling for Experiment & Payload Procedures, & autonomous crew concepts

- Safety- Improved Safety of Crew and Science Payloads
- Cost-Reduced On-Orbit Resources to Monitor Science Ops
- Need-Significant increase in Science return to researchers
- Utilization-Common

ARC

Medical Operations IVHM would develop methodologies, systems, and communication structures to seamlessly integrate Medical Operations activities with overall IVHM concepts and designs.



Improved safety of crew and vehicle

- Science & Medical Operations IVHM uses technologies, comm. structures, & data mgmt. common to other IVHM systems
- Improved awareness of crew health & performance - increased opportunities for countermeasure intervention
- Increased vehicle performance - crew performance is a critical component of IVHM
- Directly supports paperless, wireless on-orbit environment, automated mission timeline scheduling Experiment & Payload Procedures, & autonomous crew concepts

- Safety- Improved Safety of Crew and Science Payloads
- Cost-Reduced On-Orbit Resources to Monitor Crew Health & Science Ops
- Need-Medical Ops - Considered in an Integral Fashion With Overall IVHM Concepts
- Utilization-Common

DFRC

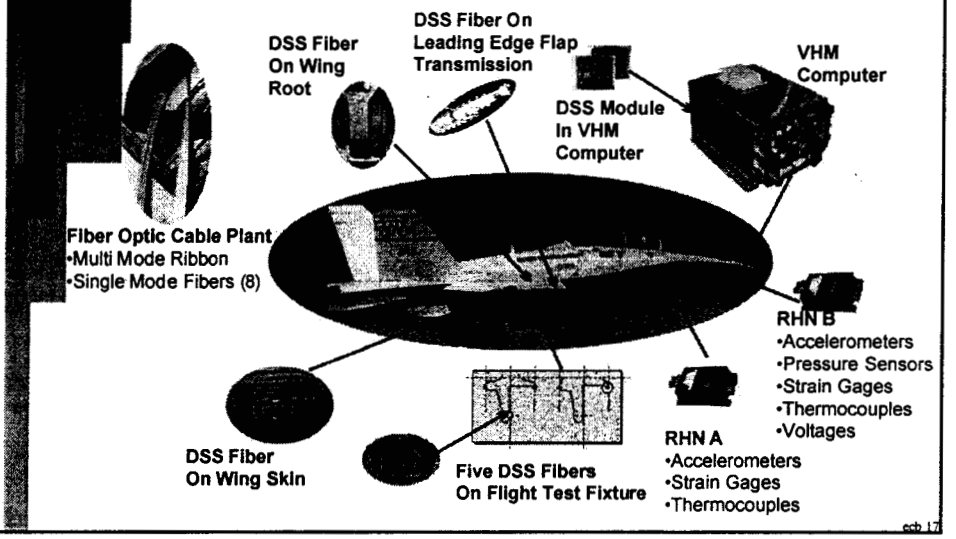
X-33 Risk Reduction Experiment

- Provide a flight platform to validate the performance of the the X-33 Vehicle Health Monitoring (VHM) system.
- Develop installation and data reduction techniques planned for the VHM system.
  - Validate data flow through the X-33 ground system.
- Assess the measurement accuracy, performance and reliability of the system in both a real world flight environment and in a well characterized laboratory environment.
  - Develop a generic flight test fixture to validate advanced sensing technologies

    (i.e. fiber optic strain, acoustic emission, etc.)
- Demonstrate the viability of the new technologies being used in the VHM system. These technologies include:
  - Installation and performance of the Generation II fiber optic cable plant.
  - Installation and performance of the X-33 VHM system.
  - Fiber Optic Distributed Strain Sensor (DSS)

DFRC

X-33 Risk Reduction Experiment



ecb 17

DFRC

X-33 Risk Reduction Experiment

- Sanders has delivered X-33 VHM components to NASA Dryden for integration and test on the Systems Research Aircraft. These components include:
  - VHM Computer with DSS Module
  - Two RHN's
  - Multi Mode Generation II Fiber Optic Cable plant
  - Single Mode Fiber Optic cable plant
- NASA Langley has supplied Optical Bragg Grading fiber to Dryden to support the DSS experiment. (59 Fiber Optic Sensors attached to 8 single mode fibers.)
- VHM Computer DSS fibers and RHN's have been integrated on the Systems Research Aircraft.
- The VHM/ RHN configuration is currently being flight tested.
- The DSS experiment will be flight tested in the Fall of 1999

ecb 18

GRC

Smart Sensors for Harsh Environments

Objective: *Develop and demonstrate integrated sensor, electronics and actuator system for intelligent, wireless, real-time, in-situ, distributed sensing and control in harsh propulsion environment.*

Approach:

- *Microfabricated, micromachined, thin film based sensors for minimally intrusive and full field coverage*
- *Micro-optical sources, sensors and connectors for light weight, safe operation.*
- *Sensor array for multifunctional and redundancy.*
- *High temperature silicon carbide electronics for in-situ data processing and wireless communication.*
- *Integrated sensors, electronics and actuator for smart in-situ diagnosis and control.*

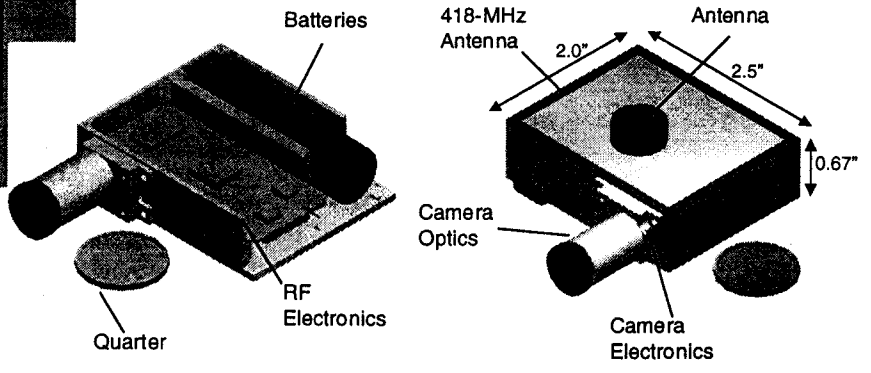
Light Source | Sensors | Electronics | Actuators

ecb 19

JPL

NASA/DARPA Wireless Camera

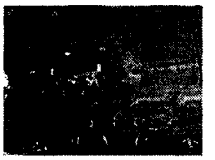
- **Wireless Camera in ~1" Cube, APS Camera Chip**
- **2.4 GHz (2.5 MBPS) Transmitter**
- **418 MHz (1.2 KBPS) Control Link**



ecb 20

KSC

- Oxygen detection smart sensors
  - –Galvanic Cell
  - –Successful flight experiments on STS-95 and STS-96

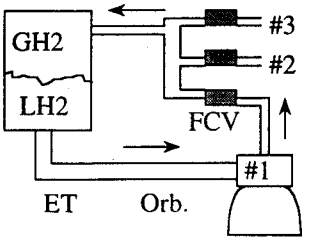


- Hydrogen detection smart sensors
  - –RS485
  - –Paladium-chrome Shottky diode "postage stamp" from Glenn Research Center/Case Western Reserve University
  - –Successful flight experiments on STS-95 and STS-96
  - –Development of combo H2/O2 smart sensor with GRC and MSFC in work

- Helium detection sensors
  - –Thermocouple
  - –Successful flight experiments on STS-95 and STS-96

KSC

- Hall Effect Sensors with Neural Network processing
  - –Non-intrusive, clip-on, torroidal shaped
  - –Health monitoring of Space Shuttle hydrogen flow control valve in ground test bed being developed



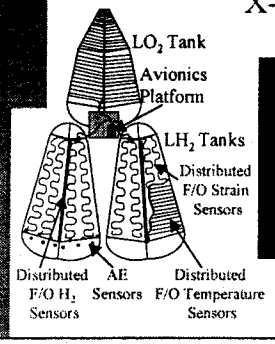
- Vacuum Jacketed line smart sensors
  - –RS485
  - –Successful flight experiments STS-95 and STS-96
  - –Ground system applications also being developed

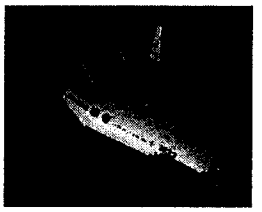
LaRC

STRUCTURES IVHM

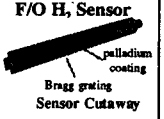
- Distributed F/O Sensors
  - Strain, temperature, leak detection
  - Potential "10,000 sensors < 1 pound"
- Acoustic Emission Damage Detection

X-33





SHUTTLE



TECH TRANSFER

- Aviation Safety
- Bridges and Civil Infrastructure
- Petrochemical Plants and Pipelines

MSFC

SFINX - Scalable Fault-tolerant Network of Intelligent Transducers

"SMART-Sheet"

RTVMS - Real Time Vibration Monitoring System

OPAD - Optical Plume Anomaly Detection

AHMS - Advanced Health Monitoring System (for SSME)

Cryogenic Flowmetering

Summary

- Expect funding (through Code R) to commence in '00
- Continue to coordinate Center activities & future Roadmap
- Expect to grow team to include industry
- Expect to team with industry for specific tasks